INTELLIGENT POWER QUALITY IMPROVEMENT UNDER DEREGULATED ENVIRONMENT

A

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By

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DECLARATION BY THE SCHOLAR

I declare that the Synopsis entitled **"Intelligent Power Quality Improvement under Deregulated Environment"** is prepared under the supervision of Dr. Y K Awasthi and Dr. Anwar S. Siddiqui and submitted for the approval of Departmental Research Committee (DRC).

Yogendra Kumar Awasthi 21/09/17
Signature of Supervisor

21.9.2017
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Intelligent Power Quality Improvement under Deregulated Environment

1. INTRODUCTION

The requirement of electrical energy is gradually growing day by day owing to the raise in the number of industries. Here, transmission and generation capacity cannot match with this growth because of several factors such as increase in expense and time needed to configure [1]. To deal with these challenges, deregulated strategy in power industry has been used. The introduction of deregulation has led to many new entities among the electricity market. Moreover, the electrical service will continually attempt to introduce innovative ideas for the betterment of utility and in turn, saves its costs, time and maximizes the profit. The deregulation period of power system function produce a lot of stress in ISO for assuring congestionless transmission framework devoid of sabotaging power system security. Hence, the entire world has been witnessed the deregulation of electricity sector during last two decades [2]. Here, the establishment of business because of deregulation changes the electricity charges to transform the money oriented business service. So, all the market players are very free to collaborate with each other in the deregulated electricity market. Here, selling and buying of electrical energy is performed by the market participants for increasing the yield and for reducing the total expense incurred for rescheduling. Meanwhile, established contract is committed only if adequate ATC is accessible for interface [3]. Generally, ATC plays a significant role for providing the information of power transfer that is used as a reference by the participants for requesting least price of electricity trading in deregulated system. Simply, ATC is a metric for transfer ability lasting inside a physical transmission network. Therefore, a fast and precise estimation of the ATC is more essential for ensuring the reliable, stable, commercial as well as secure functioning in power systems [5]. The deregulated environment also suffers from other challenges that include congestion management and voltage stability.

The CM exploits market related methods in competitive marketplace to assuage congestion and it is one of the vital tasks of the ISO [6] used to schedule, dispatch and alter the generation units. The stability limit is also considered as a most important limitation. Here,

stability limit indicates that the highest power permitted to supply via a specific point in which it is subjected to faulty flow of power. Now-a-days, voltage stability turns out to be an important factor of power system [7] [8]. Generally, voltage stability is an ability for preserving the adequate system voltages of the power system. Here, voltage stability metric is very significant and it is based on the distribution as well as availability of reactive power for assuring the existence of adequate quantity of reactive power supply of the system to protect as well as regular functioning of power system [1] [9].

Besides, the way of improving ATC, congestion management and voltage stability are performed using renowned power electronic hardware like FACTS appliances. The FACTS is employed to control the AC transmission system constraints for maximizing the controllability as well as power transfer ability [10]. Here, severalFACTS devices are used including STATCOM, IPFC, SSSC, TCSC, SVC, and UPFC [8]. Moreover, methods to solve FACTS distribution issues are categorized as three models such as heuristic models, classical models and technical models. Meanwhile, Heuristic models occupies the wide and proficient models to perform FACTS distribution [11] [12]. Some of the recent research works that improve the power quality under deregulated environment are reviewed in the subsequent Section.

Nomenclature

Abbreviation	Description
ISO	Independent System Operator
ATC	Available Transfer Capability
CM	Congestion Management
FACTS	Flexible Alternating Current Transmission System
STATCOM	Static Synchronous Compensator
IPFC	Interlink Power Flow Controller
SSSC	Static Synchronous series compensator
TCSC	Thyristor controlled series Capacitor
SVC	Static Var Compensator
UPFC	Unified Power Flow Controller
GA	Genetic Algorithm
DATC	Dynamic Available Transfer Capability

SVR	Support Vector Regression
MLP-NN	Multi-Layer Perceptron-Neural Network
CSO	Cat Swarm Optimization
RPF	Repeated Power Flow
PSO	Particle Swarm Optimization
ITVAC	Improved Time-Varying Acceleration Coefficients
MMP	Multi-objective Mathematical Programming
NNC	Normalized Normal Constraint
PSHU	Pumped Storage Hydro Unit
GSF	Generator Sensitivity Factor
BSF	Bus Sensitivity Factor
FF	FireFly
RPP	Reactive Power Procurement
OPF	Optimum Power Flow
ABC	Artificial Bee Colony
FPA	Flower Pollination Algorithm
BSOA	Brainstorm Optimisation Algorithm
SAFA	Self Adaptive FireFly Algorithm

2. RELATED WORK

2.1 ATC enhancement

In 2011, S. Rahimzadeh et al [13] have developed 2 GA based model to deal with the complications and to find out the best numbers for multi-type FACTS systems. Here, FACTS system led to the considerable minimization of the search space problem. Finally, experiment results relieved that two genetic algorithm was an efficient approach for evaluating the optimal amount of multi-type FACTS systems.

In 2014, A. Srinivasan et al [3] have introduced the bi-level programming technique to establish the best generation for increasing the ATC in bilateral/multilateral transaction. Here, ATC can be described as a metric for the transfer capacity and the system operator was accountable to the persistence of ATC. Moreover, this proposed technique was solved by means of real coded GA and moreover the proposed technique exploited for reducing the

congestion problem. Finally, the proposed technique was verified on WSCC 3 machine 9 as well as New England 10 machine 39-bus model.

In 2015, A. Srinivasan et al [5] have worked on DATC of power system. Here, they proposed SVR method and the efficiency was verified through a comparison study over MLP-NN. Moreover, this approach used to resolve the transient stability on the basis of dynamic available transfer capability. Finally, the SVR based DATC evaluation was validated using WSCC 3-machine 9-bus model as well as practical South Indian Grid model.

In 2015, B. Vijay Kumar and N.V. Srikanth [17] have introduced the hybrid technique based on optimal location for the best solution and sizing of UPFC for improving the dynamic constancy. Moreover, the advantages of the implemented approach were high accuracy and efficiency to find the correct solution. Moreover, this proposed approach was performed on IEEE 30 as well as 14 test model and the efficiency was verified over various generator errors. Finally, the comparison results revealed that the advantages of the proposed method for different approaches like GSA and ABC.

In 2016, T. Nireekshana et al [20] addressed the issue in estimation and advancement of ATC. Here, they focused in the utilization of FACTS system like TCSC and SVC for increasing power transfer transaction. Hence, they proposed CSO approach to resolve the controlling constraints of SVC as well as TCSC. Finally, experimentation analysis demonstrated in IEEE 14 and 24 bus models at the common and emergency scenarios.

2.2 Congestion Management

In 2013, C. Vaithilingam and R.P. Kumudini Devi [15] have proposed two methods on the basis of support vector machine for ATC calculation. Generally, market participants use the value of ATC for their transaction planning so ATC was very efficient. Here, first method uses conventional inputs for ATC calculation and second method uses three inputs to calculate the ATC for a given interface. Moreover, the approaches were verified in IEEE 24 and IEEE 118 Reliability test model and also the result is evaluated with the RPF results.

In 2015, Anwar Shahzad Siddiqui and Md Sarwar [2] have proposed PSO approach and the ITVAC named PSO-ITVAC. Here, this approach was adopted to reduce the congestion problem that occurs in the deregulated power system. Moreover, PSO-ITVAC approach

utilized for decreasing the expense for active power rescheduling. Finally, the result demonstrated that the active power scheduling using proposed approach works powerfully and verified in IEEE 30 and 118 bus models.

In 2016, Seyyed Ahmad Hosseini et al [19] have presented a novel MMP solution technique on the basis of NNC model. Here, it was used for elucidating the multi objective optimization issue for the congestion control. Generally, congestion management is a significant operation for the power markets and here the congestion management was modelled as an MMP issue. At last, the MMP approach was verified in New England test model as well as the outcome was evaluated through a comparison study over various congestion management technique.

In 2016, Sadhan Gope et al [21] have presented the optimization model for CM through combining the PSHU to the system. Here, two factors such as BSF and GSF were calculated. Furthermore, to reduce the expense of congestion and for enhancing the security of the model was done on the basis of PSHU. Moreover, a novel FF model has been established for CM by means of PSHU. Finally, the FF model was verified in IEEE -39 bus model.

In 2016, Sumit Verma and V. Mukherjee [23] addressed the issue in congestion which occur commonly in electricity market. Hence, they proposed proficient optimization-based method for determining the congestion issues. Moreover, this proposed method worked on the basis of FF model to improve the transmission of network congestion. To deal with the congestion problem many security measures are used such as line loading as well as load bus voltage. Finally, the proposed approach was checked in IEEE 30 and 57 benchmark systems and also concluded that the FF is a proficient method to elucidate the optimization issues.

2.3 Voltage Stability Enhancement

In 2013, Ashwani Kumar and Charan Sekhar [14] have presented congestion management on the basis of generator rescheduling for three block bid structure. Hence, they proposed generator rescheduling based congestion management technique. Additionally, the cost of congestion for all hours of a day was estimated with and without FACTS controllers. Moreover, the result demonstrates that the cost of congestion has been reduced by using the FACTS controllers than the without FACTS controllers. Finally, the proposed method validated on the basis of two test system like 24-Bus and 57-Bus system.

In 2014, Mala De and Swapan K. Goswami [1] have worked on short-term RPP problem to the deregulated power system. Moreover, RPPs have defined as OPF problem and resolved through ABC algorithm. Here, this method mainly focused on various factors such as voltage profile-index, system overall active power. Finally, the result revealed that the proposed approach acquires high performance on contingency.

In 2015, A.Y. Abdelaziz et al [4] have addressed FPA to solve the best allocation and capacitors sizing in different distribution systems. Here, main purpose of the proposed approach was deliberate for reducing the total cost as well as subsequently decreases the time. Moreover, the proposed approach is tested on IEEE 15, 18 and 118 buses which revealed the efficiency of proposed Flower Pollination Algorithm.

In 2015, A. Rezaee Jordehi [16] have proposed a novel heuristic optimisation method which can be named as BSOA it was used for determining an optimal position and FACTS compensators setting in power systems. Here, SVC and TCSC act as FACTS devices. Moreover, to solve FACTS allocation problem the BSOA method can also be treat as a suitable alternative.

In 2016, Selvarasu Ranganathan et al [22] addressed the issue to satisfy the customer need for proficient functioning of recent power system. Hence, they proposed SAFA to set the FACTS and it recognizes the relevant type, optimal potential positions as well as best constraints. Finally, the simulation work revealed capability and efficacy of the proposed method.

3. PROBLEM DEFINITION

Table I: Review on state-of-the-art methodologies to improve power quality under deregulated environment

Author [citation]	Adopted methodology	Features	Challenges
Mala De and Swapan K. Goswami [1]	ABC	➢ Easy to implement. ➢ Ability to explore local	➢ Slow down when used in sequential processing.

		solutions.	➢ Slow to obtain accurate solutions.
Anwar Shahzad Siddiqui and Md Sarwar [2]	PSO approach	➢ Fast convergence ➢ Easy to implement	➢ Trapped in local area
A. Srinivasan et al [3]	GA	➢ solves optimisation problem ➢ solves the solution scheme and solution constraint issues	➢ GA does not guarantee the static optimisation response time. ➢ Absence of exact guarantee
A.Y. Abdelaziz et al [4]	FPA	➢ solve a nonlinear design benchmark	➢ Problematic for higher dimensional problems.
A. Srinivasan et al [5]	SVR	➢ Provides regularization	➢ Parameter optimization required
S. Rahimzadeh et al [13]	GA	➢ solves optimisation problem ➢ solves the solution scheme and solution constraint issues	➢ GA does not guarantee the static optimisation response time. ➢ Absence of exact guarantee
Ashwani Kumar and Charan Sekhar [14]	Nonlinear programming	➢ Search procedure is feasible.	➢ Computational difficulties. ➢ General-purpose software is somewhat less

			effective.
C. Vaithilingam and R.P. Kumudini Devi [15]	GA	➢ solves optimisation problem ➢ solves the solution scheme and solution constraint issues	➢ Optimisation response time was not ensured by GA ➢ There was no accurate policy
A. Rezaee Jordehi [16]	BSOA	➢ Solve optimal reactive power dispatch problem.	➢ Time taken for convergence.
B. Vijay Kumar and N.V. Srikanth [17]	ABC algorithm with Gravitational Search Algorithm (GSA)	➢ Ability to explore local solutions. ➢ Parameter free and does not require tuning. .	➢ Slow down when used in sequential processing. ➢ Slow to obtain accurate solutions.
Seyyed Ahmad Hosseini et al [19]	Nonlinear programming	➢ Search procedure is feasible.	➢ Computational difficulties. ➢ General-purpose software is somewhat less effective.
T. Nireekshana et al [20]	CSO	➢ Shows enhanced efficiency in determining global optimal solution.	➢ CSO is highly complex than PSO.
Sadhan Gope et al [21]	FF algorithm	➢ Simplicity, flexibility and robustness.	➢ Limits by various local optima. ➢ FF constraints

		➢ Ease of implementation.	are static and cannot vary with time
Selvarasu Ranganathan et al [22]	SAFA	➢ Increase the chance to gain the optimality globally.	➢ Process will be slower and less convergence rate
Sumit Verma and V. Mukherjee [23]	FF algorithm	➢ Simplicity, flexibility and robustness. ➢ Ease of implementation.	➢ Limits by various local optima. ➢ FF constraints are static and cannot vary with time

4. PROBLEM FORMULATION

Numerous research contributions has been made on the literary for overcoming the shortcomings of deregulation. The SAFA used in [22] has been experimentally demonstrated for its chance to gain the optimality globally. However, the SAFA suffers from its own drawbacks such as process will be slower and less convergence rate. Moreover, FF algorithm used in [23] has advantages such as Simplicity, flexibility and robustness. Nevertheless, it gets trapped into several local optima. On the other hand, the nonlinear programming is known for its search procedure and it is very feasible [19]. However, the nonlinear programming suffers from computational difficulties. The classical evolutionary based techniques like GA and swarm intelligence techniques namely PSO have been adopted in [2] [3] [13] and [15]. These algorithms possess the ability to resolve the solution structure constraints issues. However, the basic characteristic and the drawback of these algorithms are getting trapped at the local optimal points. Generally, CSO [20] has shown its advantages such as better performance in determining the global optimal solution. However, it was very complex when comparing with PSO algorithm. On the other hand, ABC [1] [17] is parameter free and does not require tuning, unlike other algorithms. The FPA also suffers from the drawbacks in searching in high dimensional problem space. Moreover, SVR [5] algorithm provides regularization. However, it requires robust parameter optimization.

5. RESEARCH OBJECTIVES

The primary aims of this research proposal are as follows:

- To characterize the deregulated power sector with respect to the enhancement of power quality
- To understand the primary challenges and issues persist in deregulated power sector such as enhancing the ATC, congestion management and maintaining voltage stability
- To critically review the state-of-the-art methodologies to handle the aforesaid challenges and to determine the research gaps and new directions of research in the field
- To study the role of FACTS devices and the challenges reside on connecting in the deregulated network.
- To study the state-of-the-art ATC estimation algorithm and to compare it with the conventional algorithms
- To introduce advanced and adaptive optimization algorithms to enhance, maintain and manage the ATC, stability and congestion, respectively

6. PROPOSED METHODOLOGY

This proposal intends to propose adaptive and sophisticated optimization algorithms to handle the primary challenges in the deregulated power sectors such as improving ATC, maintaining voltage stability and mitigating congestion. Despite several techniques were discussed on the literary, FACTS devices occupies the significant role. Yet, the FACTS devices need best location as well as sizing for achieving the power quality improvisation proficiently and capably. It is computed through the proposed optimization algorithms. The entire methodology is carried out in three phases. At first, the initial phase of the research intends to enhance the ATC for which an intelligent model will be proposed as a function of sitting and FACTS devices sizing. In addition to this, in the second phase and third phase, individual and multi-objective models will be proposed to handle the voltage stability and the congestion management problem. Eventually, a common multi-objective model will be derived based on each objective model that all the three objectives can be met using this final objective model. Since the multi-objective model has diverse objectives and multiple parameters, an adaptive optimization algorithm based on biological inspiration will be

proposed. The inspiration will be the affect of hybridization of swarm intelligence and evolutionary computation. The resultant algorithm will solve the model effective so that the best sitting and sizing of the FACTS devices can be estimated.

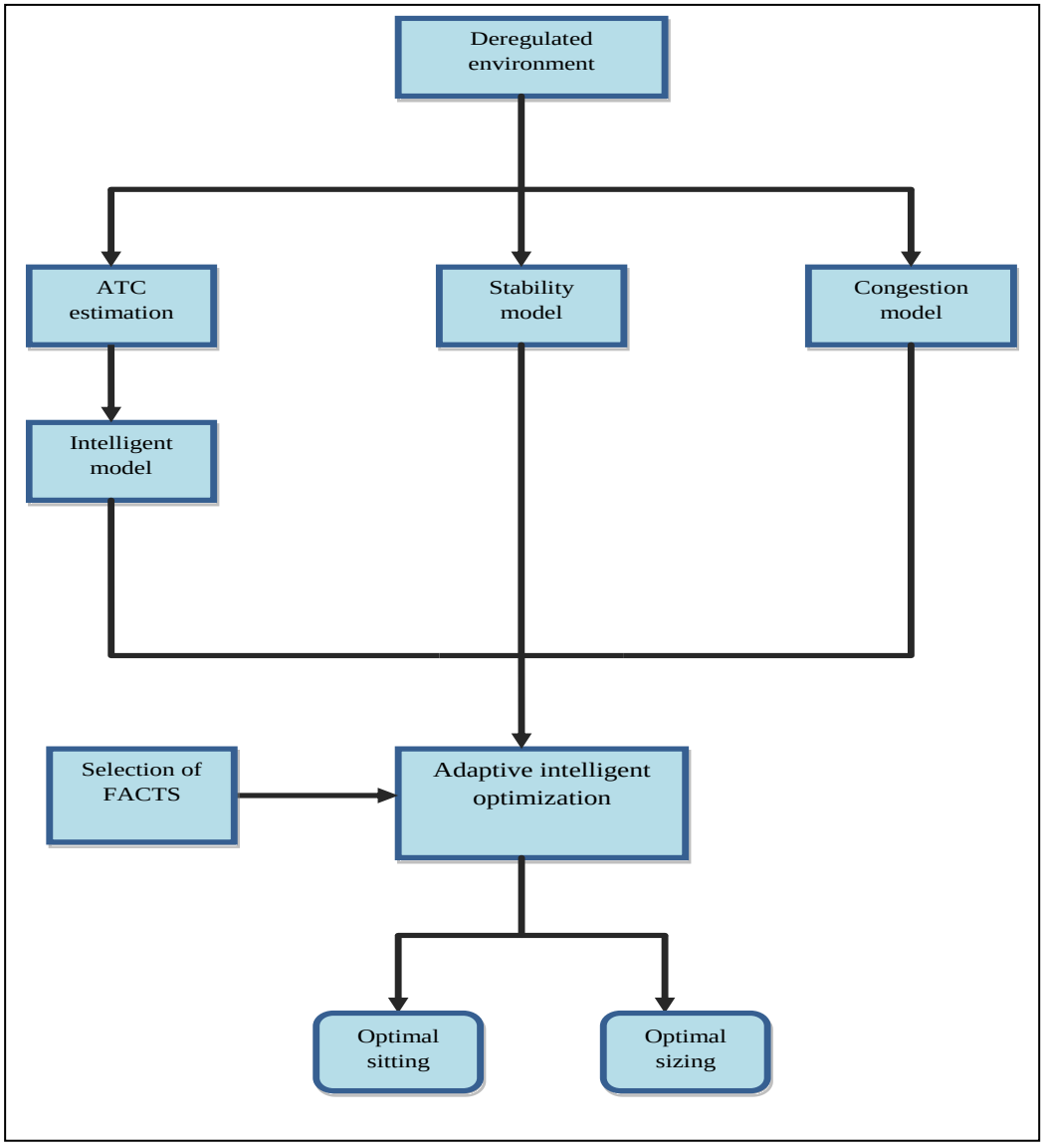

Figure 1: Proposed methodology for enhancement of deregulated power sector

7. EXPECTED OUTCOME

The proposed model and the algorithms will be simulated in the working platform of MATLAB. The experimental investigations will be carried out on the IEEE benchmark test bus systems. Multiple FACTS devices will be considered for improving the ATC, voltage

stability as well as the congestion management. Hence, the comparative analysis will be performed using the level of enhanced ATC, the operating point maintenance within the voltage stability limits and the congestion level mitigation. The cost incurred to connect the FACTS devices will also be minimized upon accomplishing the aforesaid objectives. Moreover, the convergence and statistical tests will also be done to reveal the efficiency of the proposed adaptive optimization algorithms.

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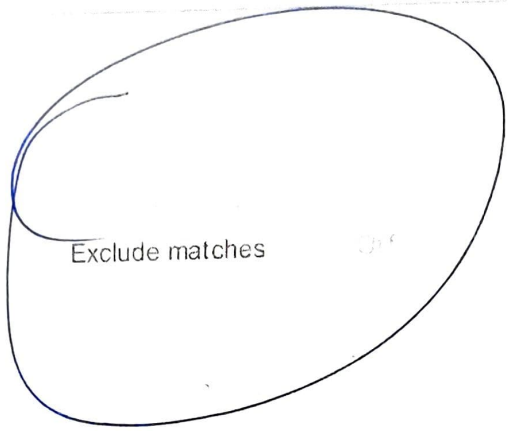
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